Caloric Equivalents for Benthic Marine Organisms from the Canadian Arctic

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ABSTRACT

Atkinson, E. G., and J. W. Wacasey. 1983. Caloric equivalents for benthic marine organisms from the Canadian Arctic. Can. Tech. Rep. Fish. Aquat. Sci. 1216: vii + 31 p.

Caloric equivalents and organic content values are presented for 97 invertebrate, 5 fish, and 2 plant species that were collected in 1976 from benthic marine stations located in Frobisher Bay, southern Baffin Island.

The report discusses the techniques employed for analysis, the problems peculiar to caloric determination and application of appropriate correction factors, and the effects of preservation on marine organisms relative to the determination of ash and caloric values.

The results, presented in tabular form, consist of collection data, data supportive of discussed techniques, caloric values, and the percent organic content for the species collected.

Key words: Canada, Arctic, Frobisher Bay, zoobenthos, marine invertebrates, demersal fish, algae, calories, ash content.

RESUME

Atkinson, E. G., and J. W. Wacasey. 1983. Caloric equivalents for benthic marine organisms from the Canadian Arctic. Can. Tech. Rep. Fish. Aquat. Sci. 1216: vii + 31 p.

Le présent rapport regroupe les équivalences caloriques et les contenus en matières organiques de 97 espèces d'invertébrés, 5 espèces de poissons et 2 espèces d'algues. Les échantillons obtenus en 1976, proviennent de stations benthiques situées dans la baie de Frobisher, dans la partie sud de la Terre de Baffin.

Le rapport discute des techniques d'analyses, des problèmes inhérents à la détermination calorique et à l'application des facteurs de correction appropriés, et des effets qu'exerce la préservation sur la détermination des contenus en matière inorganique et des valeurs caloriques des organismes marins.

Les résultats, présentés sous forme de tableaux, se composent de données propres à l'échantillonnage, de données étayant les techniques discutées, d'équivalences caloriques et de pourcentages du contenu organique des espèces collectionées.

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Table 1. Coordinates and associated data for stations sampled in Frobisher Bay, 1976.

Table 2. Comparison of organic content and mean calories per ash-free gram ($\overline{H}$) of Salmo salar muscle tissue dried at various temperatures ($t_{.05} = 4.303$).

Table 3. Comparison of mean calories per ash-free gram ($\overline{H}$) of material dried fresh, dried from formalin, and dried from alcohol after change from formalin ($t_{.05} = 4.303$).

Table 4. Comparison of percent organic content (% o.c.) of material dried fresh, dried from formalin, and dried from alcohol after change from formalin.

Table 5. Organic content and caloric values for marine zoobenthos and phytobenthos of Frobisher Bay, 1976.

INTRODUCTION

A growing interest in energy relationships in ecological work has created a demand for caloric equivalents for as wide a range of species as possible. The more traditional investigations into species-numbers relationships, diversity indices, community classifications, biomass comparisons based on whole wet weights, are gradually yielding to the more fundamental insights into energy relationships and transfers that reflect the basic organization of communities.

The purpose of this study is to present caloric equivalents for benthic marine species from the Canadian Arctic which together with the list of values previously compiled by the present authors (Atkinson and Wacasey 1976) will provide estimates for many species commonly occurring in arctic marine communities, including the majority of species that figure as dominants.

The data will be used initially to express biomass estimates as calories per unit area, providing a fundamental basis for comparing zoobenthic communities.

METHODS

Collecting and Field Processing

Samples were collected by trawl from stations in Frobisher Bay, southern Baffin Island, in August 1976. The coordinates of these stations and other relevant collection data are given in Table 1. Temperature and salinity were not measured for these stations, but based on previous data, the expected temperature range was from -1.5 to 1°C, and the expected salinity range was from 31 to 33°/$_{oo}$.

The samples were sorted fresh, identified to species and dried in a forced air oven at 75°C for 24 hours. Specimens were usually dried within 12 hours of sampling. Specimens from station 76-2 were held in trays of seawater for 48 hours until they could be transported to the field laboratory for drying. Tubes, shells, and other hard parts were removed where possible; some before and some after drying, depending on species. This includes the tubes of polychaetes, the tests of barnacles, echinoids and the holothuroid Psolus fabricii, the calcareous oral ring of the holothuroid Myriotrochus rinki, the gastropod shell utilized by the hermit crab Pagurus pubescens, and the external shells of gastropods and pelecypods. The carapace of arthropods was not removed because the sclerotized exoskeleton has caloric value. Dried specimens were transported in sealed glass jars to the Arctic Biological Station at Ste. Anne de Bellevue where ash and caloric determinations were carried out.

Laboratory Procedures for Ash and Caloric Determinations

The dried meat, or whole dry animal in the case of arthropods, sponges, and most echinoderms, was milled and/or pulverized with mortar and pestle until all the material was fine enough to pass through a 0.250 mm (#60) sieve. This ensured the homogeneity of the samples. Samples were then dried to constant weight at 100°C in a forced-air oven; the process being complete in 36 to 48 hours, depending upon species and amount of material.

Ashing was done in a muffle furnace at 500°C from four to five hours. Samples were ashed in duplicate and a mean was determined from the two values when they differed by no more than 1%.

After grinding and drying, samples were prepared for calorimetry. Samples were formed into pellets with a Parr pellet press and stored in a dessicator. While optimum pellet size was found to be 150 to 200 mg, pellets as light as 70 mg were occasionally used, depending on the nature of the organism and the amount of material available. Sample size was calculated to release no less than the recommended 200 calories. Benzoic acid in known amounts was added to samples which were less than 25% organic to promote proper ignition and ensure complete burning. All weights were determined on an electronic analytical balance to 0.02 mg accuracy.

Determinations were made with a Parr model 1243 adiabatic bomb calorimeter with automatic temperature control and using the 1107 semi-micro bomb. Most samples were burned with monel wire in a stainless steel fuel capsule. Invertebrates containing substantial

amounts of $CaCO_3$ were burned with 32 gauge platinum wire in a platinum fuel capsule, the reason for which will be given in the subsequent discussion. The use of monel instead of platinum wire is more economical and yields satisfactory results for the biological material dealt with here. The only noticeable difference is a slightly higher variability among replicate values using monel wire. This is negligible considering the inherent variability of biological material. General calorimetric procedures, as given in Parr manuals 142 and 144, and ASTM Standards for Bomb Calorimetry, were followed. All appropriate corrections for fuse wire and heat of formation of acid were applied to all calculations. Samples were determined in triplicate, and an accuracy of 3% between tests of a given sample was accepted (Golley 1961). Exceptions are noted in Table 5. Occasionally, with a sample requiring addition of benzoic acid, the three gross caloric values were within 3%, but failed to achieve this degree of accuracy when corrected for the acid. In all cases these values were accepted and a mean derived from them; such instances being noted in Table 5. The calorimeter was restandardized every two months using calorimetric standard benzoic acid at 6318 cal/g.

RESULTS AND DISCUSSION

Drying of Samples

The temperature at which material is dried in preparation for ashing and calorimetry is of importance in that it may affect the resulting values. After some experimentation, a temperature of 100°C was decided upon.

Portions of several samples were dried at temperatures from 80 to 120°C, in increments of ten degrees, then determined for caloric content. In general, values increased from 80 to 100°C, presumably from driving off increased amounts of moisture. From 100 to 120°C values declined, presumably from driving off volatile organic components. A particularly marked demonstration of this was shown in samples of muscle tissue from the Atlantic salmon, Salmo salar, which was treated as above. Percent organic content and caloric values determined at each drying regime are presented in Table 2. The significance of the difference between a caloric value and its adjacent value from the next lowest drying regime is evident from the adjacent "t" value as determined from Student's "t" test. Maximum caloric value is achieved when material is dried at 100°C. The increase from 80 to 90°C was not significant at the .05 level, but from 90 to 100°C the increase was highly significant. Similarly, neither the decline from 100 to 110°C, nor that from 110 to 120°C was significant, but that from 100 to 120°C was. The organic content values indicate that water loss stabilized at or around 100°C. As no apparent reduction in organic content occurred between 100 and 120°C, the reason for the decline in caloric value may

be a change in the energy states of certain organic compounds due to the heat, rather than a direct volatilization of organic constituents. Since the lipid content of this tissue was particularly high, it may be inferred that most organisms would not be detrimentally affected by drying at 100°C. Organisms containing large amounts of hydrated skeletal material such as $CaCO_3$ and SiO_2 would have their caloric values more accurately estimated by drying at the highest temperature consistent with maintaining the integrity of the organic structure. The drying temperature of 105°C, suggested by Cummins and Wuycheck (1971), may be the most suitable, since it would ensure that all water not chemically bonded would be removed. The results of our experiments support this; however, samples with known organic fractions that volatilized at these temperatures would be more appropriately dried by freeze drying.

Ashing

Test samples ashed for varying periods up to 24 hours at 500°C indicated that combustion was complete after four hours. A loss in ash weight was observed after 24 hours, with a maximum of 0.82% in the species tested. Since various salts decompose at temperatures higher than 500°C (Paine 1966, 1971), it seems advisable to ash for no longer than five hours at 500-550°C. Ash values derived from the calorimeter are usually in error and should not be used. This has been discussed by the present authors (1976) and by others (Paine 1964, 1971; Cummins and Wuycheck 1971). Samples were ashed in duplicate and a mean was

determined from the two values when they differed by no more than 1%. Exceptions to this are noted in Table 5. For convenience, percent organic content rather than percent ash has been presented.

Storage of Samples

It has been suggested by Cummins and Wuycheck (1971) that material be stored frozen from the fresh state. However, material that has been dried at 100-105°C, and presumably freeze-dried material as well, appears to keep in satisfactory condition if stored in air-tight containers. Three species of invertebrates, dried at 100°C and stored in glass vials with either polyethylene snap-caps, or bakelite screw caps with conical polyethylene seals, were redetermined after six years storage. Two showed a slight decrease in caloric value of 0.46 and 1%, and one showed an increase of 0.67%, none of which was significant at the .05 level. Freezing of dried material might be expected to provide the most satisfactory method of long term storage, should it be desired to retain the remains of determined samples for future reference.

Sources of Error and Applied Corrections

Paine (1964, 1966, 1975) has discussed a wide variety of potential sources of error in deriving caloric values. The procedures described above have minimized many of these, including: mensural errors, fuse wire corrections, heat of acid formation, addition of carrier material to ensure complete combustion, drying technique, and method of ash determination. Two other potentially large sources of error are the

influence of water retained by hydrated skeletons such as SiO_2 and $CaCO_3$, and the endothermic breakdown of salts, principally $CaCO_3$, which may occur in the bomb. Methods of correcting for these sources of error have been determined and discussed by Atkinson and Wacasey (1976). The organic content values for all echinoderms whose skeletons were not removed, and for the decapod Pagurus pubescens, whose exoskeleton contains large amounts of $CaCO_3$, have been corrected for water of hydration in the following manner. Based on the mean organic content of species without skeletons and judged to be similar in trophic level, the assumption was made that weight loss on ashing of a skeletal bearing species represented 85% of the dried flesh alone with the remaining 15% representing ash from the flesh. The ash associated with the flesh was calculated, subtracted from total ash, and the difference taken to be the $CaCO_3$ content for that species. Using the empirical value of 0.27 g mol wt of water associated with each g mol wt of $CaCO_3$ (Atkinson and Wacasey 1976), the water of hydration was calculated, expressed as a percent of whole dry weight, and used to adjust the organic content values. Water of hydration values for the siliceous skeletons of the sponges Polymastia mammillaris and Tetilla sibirica were determined directly and the organic content adjusted accordingly. Values for Haliclona gracilis and Lissodendoryx indistincta were corrected in a similar fashion to species containing $CaCO_3$, assuming that weight loss on ashing represented 75% of the flesh and that 0.21 g mol wt of water was associated with one g mol wt of SiO_2. This value was obtained as the average of three directly determined species. The caloric values in Table 5 have been corrected, where appropriate, for water of hydration.

Where $CaCO_3$ constitutes 25% or more of total dry weight, a significant reduction in estimated caloric value can be expected due to the endothermic breakdown of $CaCO_3$ at high temperatures in the bomb (Paine 1966, Atkinson and Wacasey 1976). Samples known to contain large amounts of skeletal material in the form of $CaCO_3$ (echinoderms from which skeletons were not removed and the hermit crab Pagurus pubescens) were ignited in the calorimeter with platinum fuse wire to minimize the problem of fusing wire globules with the ash, thus permitting calorimeter ash to be accurately weighed after appropriate drying. The difference between muffle furnace ash (uncorrected for H_2O of hydration) and calorimeter ash was taken to be the weight of CO_2 evolved in the reaction, $CaCO_3 \rightarrow CaO + CO_2$, and lost on opening the bomb. An empirical value of 0.77 cal/mg of ash weight lost (CO_2 evolved) was used to calculate the amount of heat consumed by the dissociation of $CaCO_3$ (Atkinson and Wacasey 1976). This is equivalent to 0.33 cal/mg of $CaCO_3$ broken down, and falls between Paine's (1966) empirical value of 0.14 cal/mg and the theoretical value of 0.43 cal/mg. The caloric values in Table 5 have been corrected, where appropriate, for $CaCO_3$ dissociation. Values for fish have not been similarly adjusted, since their skeletons were estimated to make up less than 25% of the total dry weight, and salts other than $CaCO_3$, such as $Ca_3(PO_4)_2$, may make up a significant proportion of the skeleton and for which suitable correction factors are unavailable.

Application of the above correction factors for water of hydration and $CaCO_3$ breakdown may involve some error but this error is thought to be negligible compared to the inaccuracy of an uncorrected value.

Caloric Determination of Preserved Material

To determine the effects of formalin and alcohol preservation on the caloric value and organic content of marine organisms, and to establish whether such results reliably represent values obtained from fresh material, the following experiment was conducted. Populations of species representative of several of the dominant taxa were collected and divided into three equal portions. One third was dried fresh, the other two thirds was preserved in a 10% formalin solution and allowed to stabilize for several months. Half of this material was then dried out of formalin; the balance was transferred to 70% ethanol and then dried after reaching stability. Drying and all other preparations were carried out as described in the Methods section. Caloric value and organic content were determined for each of the three conditions, and the results are presented in Tables 3 and 4, respectively.

An increase in caloric value ranging from 2.26 to 11.59% was observed in the six species, five invertebrate and one plant, which had been preserved in formalin. Four out of six of these increases were significant at the .05 level, using Student's "t" test. Following additional fixation in alcohol, four of six values increased by 0.11 to 4.79%, one being significant, while two values decreased from formalin by 1.89 and 7.05%, both being significant. The net effect from fresh to alcohol preservation with intervening retention in formalin was an increase in five values varying from 1.94 to 16.94%, four of these being significant. The single net loss was not significant. There appears to be a general trend for caloric values to increase with preservation, although in degree this is not consistent.

The effects of preservation on organic content are similarly erratic. From fresh to formalin three values declined, ranging from 1.39 to 8.56%, and three increased varying from 0.64 to 19.74%. In alcohol, five values increased from their formalin counterparts from 4.03 to 11.72%, while one fell from its respective formalin value by 0.89%. The net effect from fresh to alcohol preservation with intervening retention in formalin was a gain in four values from 3.30 to 31.46%, and a loss in two of 1.48 and 3.88%. The indication is that formalin alone is inconsistent in its effect, while further fixation in alcohol tends to increase organic content. As for the caloric value, the magnitude of the change is unpredictable.

In the absence of biochemical analysis, the mechanism of these changes is largely speculative. The tendency towards a net gain in organic content may result from dissolving some of the inorganic fraction of a sample. The general net gain in caloric value may in some cases be due to chemical recombination into new organic compounds of higher energy; the losses possibly explained by a simple solvent and leaching effect on various organic fractions, presumably having its strongest effect on lipids. Since the observed changes are not all in the same direction, the constitution of the specific organism must affect the results. It is also probable that the observed effects would have been different in degree had the volume of sample to volume of preservative ratio been different; i.e. a different equilibrium would have been reached with a greater or lesser amount of preservative surrounding the sample.

Since the populations of the above species were split into 3 portions on a volume basis with no systematic attempt to divide size classes equally, it is possible that individual differences may have tended to obscure a more clear-cut result. Consequently, a similar test was run on subsamples of salmon muscle tissue, which is homogeneous and should tend to obviate such differences. The caloric values and organic content are presented at the ends of Tables 3 and 4, respectively. The caloric value of the muscle tissue in formalin dropped significantly, and again on transfer to alcohol, although not significantly (.05 level). This is contrary to the trend in invertebrate material where there was an increase in caloric value with preservation. Since salmon muscle has a high lipid content, the result seems to confirm the suspicion of a leaching effect of preservation on lipids. Little can be said concerning the organic content values, except that the observed increase in alcohol preservation follows the previously observed trend.

Despite the observed trends toward increased organic content and caloric value in preserved material, changes are not always in the same direction, and the magnitude of the changes is quite variable, indicating preserved material does not provide reliable results.

Where a caloric equivalent is required but fresh material is unavailable for analysis, the best estimate to use would be the value of a similar species, preferably from the same genus, or else the mean derived from available values for a given taxon. Lacking these, a value of 5436 cal/ash-free gram may be applied, as representing the mean of all invertebrate values (Atkinson and Wacasey 1976 and present). The

potential source of error inherent in the application of representative, rather than determined values, is more critical with organic content than with caloric content. Among various values available for a given species, organic content values usually show greater variability than do the corresponding caloric estimates.

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Table 1. Coordinates and associated data for stations sampled in Frobisher Bay, 1976.

Station	Date	North latitude	West longitude	Depth (m)
76-5	4 Aug	63°40'	68°26'	60
76-5	5 Aug	63°40'	68°26'	60
76-5	21 Aug	63°40'	68°26'	60
76-2	13 Aug	62°34.3'	65°43.3'	90
76-25	18 Aug	63°43.3'	68°31.4'	30
76-LA	20 Aug	63°44'	68°30.5'	littoral
76-LB	19 Aug	63°43.6'	68°32'	littoral

Table 2. Comparison of organic content and mean calories per ash-free gram ($\bar{H}$) of Salmo salar muscle tissue dried at various temperatures ($t_{.05} = 4.303$).

Drying temp. °C	% organic content	$\bar{H}$	% change	t	% change 100-120°C	t
80	93.15	6626				
90	93.10	6645	+0.3	0.693		
100	92.26	6738	+1.4	7.482		
110	92.24	6701	-0.6	1.277		
120	92.43	6602	-1.5	2.712	-2.0	5.761

Table 3. Comparison of mean calories per ash-free gram ($\bar{H}$) of material dried fresh, dried from formalin, and dried from alcohol after change from formalin ($t_{.05} = 4.303$).

Species	$\bar{H}$ fresh	$\bar{H}$ formalin	% change	t	$\bar{H}$ alcohol	% change from formalin	t	% change from fresh	t
Nicomache lumbricalis	5481	6009	+9.63	22.273	6150	+2.35	0.819	+12.21	29.049
Lebbeus groenlandicus	5881	6014	+2.26	8.974	6020	+0.10	0.386	+2.36	8.067
Strongylocentrotus droebachiensis	6076	6780	+11.59	14.343	7105	+4.79	4.508	+16.94	17.012
Hiatella arctica	5607	5826	+3.91	5.056	5716	-1.89	5.537	+1.94	2.747
Musculus discors	5716	6121	+7.09	12.042	6128	+0.11	0.213	+7.21	10.450
Laminaria sp.	4063	4339	+6.79	6.263	4033	-7.05	7.013	-0.74	1.049
Salmo salar muscle	6738	6418	-4.75	10.580	6203	-3.39	3.191	-7.94	8.447

Table 4. Comparison of percent organic content (% o.c.) of material dried fresh, dried from formalin, and dried from alcohol after change from formalin.

Species	% o.c. fresh	% o.c. from formalin	% change	% o.c. from alcohol	% change from formalin	% change from fresh
Nicomache lumbricalis	69.03	60.47	-8.56	65.15	+4.68	-3.88
Lebbeus groenlandicus	70.00	68.61	-1.39	73.30	+4.69	+3.30
Strongylocentrotus droebachiensis	58.62	53.11	-5.51	57.14	+4.03	-1.48
Hiatella arctica	77.99	78.63	+0.64	83.74	+5.11	+5.75
Musculus discors	81.65	90.23	-8.58	89.34	-0.89	+7.69
Laminaria sp.	53.13	72.87	+19.74	84.59	+11.72	+31.46
Salmo salar muscle	92.26	98.55	+6.29	99.67	+1.12	+7.41

Table 5. Organic content and caloric values for marine zoobenthos and phytobenthos of Frobisher Bay, 1976.

Species	Station	Date 1976	% organic content	cal/ash-free g	SD	95% confidence limits
ANNELIDA: Polychaeta						
Amphitrite groenlandica	76-5	4 Aug	71.1	5777	±11.3	± 34
Branchiomma infarcta	76-5	5 Aug	80.6	5554	±49.8	±151
Enipo gracilis	76-5	4 Aug	76.3	5326	±26.7	± 81
Harmothoe oerstedi	76-5	4,5 Aug	82.8	5391	±54.8	±167
Harmothoe oerstedi	76-2	13 Aug	77.5	5373	±36.6	±111
Lumbrineris fragilis	76-5	5 Aug	88.4	5696	±11.7	± 36
Myriochele heeri[1]	76-5	4 Aug	19.9	5422	±45.8	±139
Nephtys ciliata	76-2	13 Aug	72.9	5462	±53.8	±164
Nephtys paradoxa	76-5	4 Aug	84.4	6079	±67.0	±204
Nicomache lumbricalis	76-5	4 Aug	69.0	5481	±28.1	± 85
Pherusa plumosa[2,3]	76-5	5 Aug	42.7	5299	±33.7	±428
Phyllodoce groenlandica[3]	76-5	4 Aug	71.6	5601	±79.4	±1009
Pista flexuosa[3]	76-5	5 Aug	58.6	5771	±10.7	±136
Pista maculata	76-5	5 Aug	78.2	6061	±16.7	± 51
Praxillella praetermissa	76-25	18 Aug	76.2	5474	±61.6	±188
Sabella crassicornis	76-5	5 Aug	82.4	5618	±19.4	± 59
Scalibregma inflatum[2,4]	76-5	5 Aug	43.3	5048	--	--

Table 5. Continued.

Species	Station	Date 1976	% organic content	cal/ash-free g	SD	95% confidence limits
ANNELIDA: Polychaeta						
Thelepus cincinnatus	76-5	5 Aug	71.6	5389	±11.3	± 34
Thelepus cincinnatus	76-2	13 Aug	87.2	5865	±42.3	±129
ARTHROPODA: Amphipoda						
Anonyx nugax	76-5	4,5 Aug	65.0	5955	±14.8	± 45
Anonyx nugax	76-2	13 Aug	67.2	6025	±26.8	± 82
Gammarus oceanicus/setosus	76-LA	20 Aug	65.2	5537	±10.4	± 32
Paramphithoe hystrix	76-5	4,5,21 Aug	55.9	5502	±31.4	± 95
Stegocephalus inflatus	76-5	4,5,21 Aug	65.2	5626	± 9.6	± 29
ARTHROPODA: Cirripedia						
Balanus balanoides	76-LB	19 Aug	79.7	5712	±50.3	±153
Balanus balanus	76-5	4,5 Aug	72.8	5400	±50.3	±153
Balanus crenatus	76-5	4,5 Aug	67.3	5432	±47.5	±145
ARTHROPODA: Decapoda						
Argis dentata	76-5	21 Aug	79.6	5849	± 4.7	± 14

Table 5. Continued.

Species	Station	Date 1976	% organic content	cal/ash-free g	SD	95% confidence limits
ARTHROPODA: Decapoda						
Lebbeus groenlandicus						
adults without eggs	76-5	21 Aug	75.6	5691	±11.3	± 34
juveniles[5]	76-2	13 Aug	62.3	5409	±29.9	± 91
adults	76-2	13 Aug	71.3	5690	±18.8	± 57
females with eggs	76-2	13 Aug	70.0	5881	±20.3	± 62
Pagurus pubescens	76-2	13 Aug	53.8	5638	±39.8	±121
Sclerocrangon boreas						
females with eggs	76-5	5 Aug	79.6	5701	±17.4	± 53
juveniles[5]	76-2	13 Aug	67.1	5434	±12.9	± 39
adults	76-2	13 Aug	78.8	5478	±22.2	± 68
females with eggs	76-2	13 Aug	75.7	5629	±10.6	± 32
Spirontocaris spinus	76-5	21 Aug	73.1	5532	± 9.7	± 30
juveniles[5]	76-2	13 Aug	62.8	5477	±43.5	±132
adults	76-2	13 Aug	65.5	5702	±31.4	± 96
females with eggs	76-2	13 Aug	69.7	5737	±10.0	± 30

Table 5. Continued.

Species	Station	Date 1976	% organic content	cal/ash-free g	SD	95% confidence limits
ARTHROPODA: Isopoda						
Arcturus baffini	76-5	4,5 Aug	48.4	5407	±15.3	± 47
Arcturus baffini	76-2	13 Aug	53.0	5512	±37.1	±113
BRACHIOPODA						
Hemithyris psittacea[6,7]	76-5	4,5 Aug	56.7	5576	±148.5	±452
CHORDATA: Ascidiacea						
Boltenia echinata[8]	76-5	5 Aug	11.9	4908	±139.0	±423
Boltenia ovifera[3]	76-2	13 Aug	69.9	5461	±33.2	±421
Dendrodoa aggregata	76-2	13 Aug	52.3	5026	±70.2	±213
Pelonaia corrugata[6]	76-5	5 Aug	42.0	4653	±52.2	±159
Styela rustica	76-5	5 Aug	32.8	5061	±45.6	±139
ECHINODERMATA: Asteroidea						
Henricia eschrichti	76-5	4,5 Aug	45.8	5345	±54.9	±167
Henricia scabrior	76-5	4,5 Aug	55.8	5493	±59.7	±181
Leptasterias polaris	76-2	13 Aug	48.3	5475	±60.4	±184

Table 5. Continued.

Species	Station	Date 1976	% organic content	cal/ash-free g	SD	95% confidence limits
ECHINODERMATA: Asteroidea						
Pteraster pulvillus	76-5	5 Aug	45.1	5172	±27.4	± 83
Solaster papposus	76-5	21 Aug	45.7	5794	± 9.1	± 28
Solaster papposus	76-2	13 Aug	39.2	5626	±25.8	± 78
Solaster syrtensis	76-5	4,5 Aug	45.6	5291	± 8.5	± 26
ECHINODERMATA: Crinoidea						
Heliometra glacialis	76-2	13 Aug	24.2	5591	±47.2	±143
ECHINODERMATA: Echinoidea						
Strongylocentrotus droebachiensis	76-5	5 Aug	46.2	5388	± 5.0	± 15
Strongylocentrotus droebachiensis	76-2	13 Aug	58.6	6076	±36.1	±110
ECHINODERMATA: Holothuroidea						
Cucumaria frondosa	76-2	13 Aug	75.3	5701	±62.7	±191
Myriotrochus rinki	76-2	13 Aug	25.0	4811	±29.4	± 89
Psolus fabricii	76-5	4,5 Aug	64.1	5764	±63.8	±194
Thyonidium sp.	76-5	5 Aug	68.5	5459	±51.7	±157

Table 5. Continued.

Species	Station	Date 1976	% organic content	cal/ash-free g	SD	95% confidence limits
ECHINODERMATA: Ophiuroidea						
Ophiopus arcticus[8]	76-5	4,5 Aug	20.4	5013	±105.4	±321
Ophiura sarsi[8]	76-5	21 Aug	17.6	5461	±154.4	±469
Ophiocten sericeum	76-5	5 Aug	15.9	5920	±54.6	±166
MOLLUSCA: Cephalopoda						
Rossia molleri/palpebrosa	76-5	21 Aug	87.2	5769	±66.0	±201
MOLLUSCA: Gastropoda						
Buccinum angulosum	76-2	13 Aug	88.9	5717	±24.9	± 76
Buccinum hydrophanum	76-5	21 Aug	90.4	5627	±25.9	± 79
Buccinum hydrophanum	76-2	13 Aug	89.4	5826	±15.0	± 46
Buccinum scalariforme (=B. tenue)	76-2	13 Aug	90.9	5857	±26.1	± 80
Capulacmaea radiata	76-5	4,5 Aug	88.0	5716	±22.5	± 68
Colus islandicus	76-5	5 Aug	88.4	5556	±27.8	± 85
Colus pubescens[2]	76-5	4,5 Aug	86.5	5513	±45.9	±140
Colus tortuosus	76-5	4,5 Aug	80.9	5948	±49.3	±150
Dendronotus robustus[6]	76-5	4 Aug	70.5	5578	±39.5	±121

Table 5. Continued.

Species	Station	Date 1976	% organic content	cal/ash-free g	SD	95% confidence limits
MOLLUSCA: Gastropoda						
Lepeta caeca[2,3]	76-5	4,5 Aug	69.5	5682	±49.2	±626
Littorina saxatilis	76-LA	20 Aug	78.2	5541	±23.4	± 71
Lunatia pallida	76-5	4,5 Aug	85.9	5521	±34.1	±104
Margarites costalis	76-5	4,5 Aug	68.4	5655	±63.5	±193
Margarites helicinus	76-5	4,5 Aug	70.7	5557	±14.7	± 45
Marsenina glabra	76-5	5 Aug	90.0	5724	±24.2	± 74
Natica clausa[6]	76-5	4,5 Aug	91.7	5369	±46.8	±143
Neptunea despecta	76-5	5 Aug	91.2	5530	± 9.4	± 29
Onchidiopsis glacialis	76-5	5 Aug	83.9	5656	±21.9	± 67
Velutina plicatilis	76-5	4,5 Aug	83.9	6099	±62.5	±190
Velutina undata	76-5	4,5 Aug	84.2	5605	±32.6	± 99
Velutina velutina	76-5	4,5 Aug	81.3	5338	±12.4	± 38
MOLLUSCA: Pelecypoda						
Astarte borealis	76-5	4,5 Aug	81.3	5570	±79.8	±243
Chlamys islandica	76-5	21 Aug	87.2	5417	±36.8	±112
Clinocardium ciliatum	76-5	5 Aug	86.2	5576	±29.7	± 90

Table 5. Continued.

Species	Station	Date 1976	% organic content	cal/ash-free g	SD	95% confidence limits
MOLLUSCA: Pelecypoda						
Hiatella arctica	76-5	4 Aug	76.3	5524	±60.1	±183
Macoma calcarea	76-5	4 Aug	77.3	5340	±23.2	± 70
Macoma calcarea	76-2	13 Aug	80.3	5552	±46.9	±143
Macoma moesta[6]	76-5	4,5 Aug	77.1	5372	±54.3	±165
Macoma moesta[6]	76-2	13 Aug	76.3	5440	±99.3	±302
Musculus discors	76-5	4,5 Aug	81.7	5716	±49.1	±149
Musculus niger	76-5	4,5 Aug	87.3	5544	±22.4	± 68
Mya truncata	76-5	4,5 Aug	61.8	5288	±16.1	± 49
Nucula belloti	76-2	13 Aug	81.0	5884	±11.3	± 35
Nuculana minuta[2,3]	76-5	4,5 Aug	69.4	5522	± 4.6	± 58
Nuculana pernula	76-5	4,5 Aug	71.1	5520	±21.6	± 66
Pandora glacialis[2]	76-5	4,5 Aug	78.4	5123	±63.7	±194
Periploma abyssorum[3]	76-5	4,5 Aug	49.5	5276	±50.1	±637
Serripes groenlandicus	76-2	13 Aug	84.8	5416	±51.5	±157
Thyasira gouldi[2]	76-25	18 Aug	78.5	5321	± 4.5	± 14
Yoldia h. hyperborea	76-5	4,5 Aug	80.0	5404	±19.2	± 59

Table 5. Continued.

Species	Station	Date 1976	% organic content	cal/ash-free g	SD	95% confidence limits
NEMERTINA						
Nemerteans	76-5	4 Aug	80.1	5325	±11.4	± 35
PORIFERA						
Haliclona gracilis	76-5	21 Aug	34.2	5629	±46.7	±142
Lissodendoryx indistincta	76-5	21 Aug	26.0	5477	±11.7	± 36
Polymastia mammillaris	76-5	21 Aug	27.5	5431	±22.3	± 68
Tetilla sibirica	76-5	5 Aug	18.1	5541	±12.6	± 38
SIPUNCULIDA						
Golfingia margaritacea	76-5	4 Aug	58.0	5367	±76.0	±231
FISH						
Boreogadus saida	76-5	21 Aug	86.8	6632	±50.1	±152
Eumicrotremus sp. female with eggs	76-5	21 Aug	85.0	6652	±74.5	±227
Icelus bicornis	76-5	5 Aug	75.5	6045	±45.3	±138
Icelus bicornis	76-2	13 Aug	71.8	5833	±72.1	±219

Table 5. Continued.

Species	Station	Date 1976	% organic content	cal/ash-free g	SD	95% confidence limits
FISH						
Lycodes sp.	76-2	13 Aug	76.6	5702	± 9.8	± 30
Myoxocephalus quadricornis	76-2	13 Aug	75.1	5597	±67.8	±206
ALGAE						
Fucus sp.	76-5	5 Aug	71.7	4517	±15.6	± 47
Laminaria sp.[9]	76-5	5 Aug	55.0	4640	±27.2	± 83
Laminaria sp.[9]	76-2	13 Aug	53.1	4063	±35.8	±109

Explanatory notes to Table 5

1. The sample contained an indeterminate amount of tube material. The organic value is not an accurate indication of the organic content of the dry meat alone.

2. Percent organic content was not determined in duplicate due to lack of material.

3. Only two caloric determinations were made due to lack of material.

4. Only one caloric determination was made due to lack of material.

5. Juveniles comprise several size classes, from approximately half to three quarters of maximum adult size.

6. Duplicate organic content values were more than 1% apart. There was insufficient material for additional determinations.

7. Triplicate caloric values varied by more than 3%. There was insufficient material for additional determinations.

8. Triplicate caloric values varied by more than 3% due to use of benzoic acid.

9. Determinations were made on the blade only, with stipe removed.